ELEVATOR ROPE ARRANGEMENT

This application is a divisional of co-pending Application No. 09/337,739, filed on June 22, 1999, which is a continuation of PCT International Application No. PCT/FI97/00824 filed on December 19, 1997, and for which priority is claimed under 35 U.S.C. § 120. The entire contents of each of the above-identified applications are hereby incorporated by reference. This application also claims priority of Application Nos. 965243 filed in Finland on December 30, 1996 and 965242 filed in Finland on December 30, 1996 under 35 U.S.C. § 119.

Field of the Invention

The present invention relates to an elevator rope arrangement.

Description of the Background Art

In traction sheave elevators, the elevator car and counterweight are suspended on round steel ropes. Normally, the same ropes act both as suspension ropes, whose function is to support the elevator car and counterweight, and as hoisting ropes serving to move the elevator car and counterweight. Therefore, the ropes must be designed to carry the entire load, even if, when a counterweight is used, the force needed to move the elevator is very small - in an extreme case nearly zero when the counterweight and the elevator car with the car load are equal in weight.

In prior art, there are also solutions having separate suspension ropes and hoisting ropes. Such an elevator is presented e.g. in US patent specification 5,398,781. In the elevator described in this specification, the suspension rope is attached to the top part of the elevator car and passed via diverting pulleys to a lever element on the counterweight. The hoisting rope is attached either to the top or bottom part of the elevator car and, like the suspension rope, passed via diverting pulleys and the traction sheave of the hoisting machine to a lever element on the counterweight. To compensate for rope elongation, the elevator described in this specification comprises a lever element fitted in conjunction with the counterweight and acting as a tensioning device. This patent focuses especially on the tensioning of the hoisting rope and contains no mention of any details of the

suspension ropes or hoisting ropes. Neither does it describe any advantages that could be achieved by separate implementation of hoisting ropes and suspension ropes.

The hoisting ropes generally used are steel cables, whose friction coefficient is, however, so low that it has to be increased e.g. by using traction sheaves with different types of grooves or by increasing the angle of contact or angle of rotation of the rope around the traction sheave. In addition, a hoisting rope made of steel functions as a kind of sound bridge between the hoisting motor drive and the elevator car, transmitting noise from the hoisting machinery to the elevator car and thus impairing passenger comfort.

A further drawback with prior-art solutions using steel hoisting ropes is that the bending radius of the rope is relatively large, which means that the traction sheave and diverting pulleys must have a large diameter. Another drawback with steel rope is that the weight of the rope imposes a limit on the hoisting height of elevators. Moreover, steel ropes are liable to corrosion, so they require regular maintenance.

Specification EP 672 781 A1 presents a round elevator suspension rope made of synthetic fibersfibers. Topmost on the outside it has a sheath layer surrounding the outermost strand layer. The sheath layer is made of plastic, e.g. polyurethane. The strands are formed from aramid fibers. Each strand is treated with an impregnating agent to protect the fibers. Placed between the outermost and the inner strand layers is an intermediate sheath to reduce friction. To achieve a nearly circular strand layer and to increase the volumetric efficiency, the gaps are filled with backfill strands. The function of the top-most sheath layer is to ensure a coefficient of friction of desired magnitude on the traction sheave and to protect the strands against mechanical and chemical damage and UV radiation. Thus, the load is supported exclusively by the strands. As compared with corresponding steel rope, a rope formed from aramid fibers has a substantially larger load bearing capacity and a specific weight equal to only a fifth or a sixth of the specific weight of corresponding steel rope.

A drawback with these prior-art solutions, in which a round elevator rope formed e.g. from synthetic fibers, is that the rope has a relatively large bending radius, requiring the use of

large-diameter traction sheaves and diverting pulleys. Further, there occurs a fair deal of sliding of the strands and fibers in relation to each other. Moreover, the ratio of volume to area is high, which means that frictional heat will not be effectively removed from the rope and the rope temperature is therefore liable to rise unduly.

Summary of the Invention

The object of the present invention is to eliminate the drawbacks of prior art and achieve a new type of elevator rope arrangement, in which the elevator ropes are divided into two categories: a) suspension ropes, whose function is to connect the elevator car and the counterweight to each other and to support them, and b) a new type of hoisting rope made of synthetic material, whose function is to receive the unbalance between the counterweight on the one hand and the elevator car and its load on the other hand and to move the elevator car.

In this arrangement, friction is not a necessary consideration regarding the suspension ropes, so these can be made of steel cable. By contrast, the hoisting ropes are thin ropes of synthetic material, in which the tensile strength of the structure is formed by longitudinal strands of e.g. aramid fibers. These strands are surrounded by a sheath that binds the strands of each rope together and provides a good friction coefficient against the traction sheave. The sheath is made of e.g. polyurethane, which gives a multifold friction coefficient as compared e.g. with steel rope. Details of the features characteristic of the solution of the invention are given below.

The hoisting ropes now only have the bear a fraction of the loads of the elevator, as they need not support the load resulting from the passengers of goods being transported and the counterweight. Therefore, the elevator hoisting rope of the invention can be made very thin, which means that it has a small bending diameter. The hoisting rope can also be implemented as a flat rope, in which case the sheath of the hoisting rope is of a planar shape and, in cross-section, the hoisting rope thus has a width substantially larger than its thickness.

The thin and flat hoisting rope allows the use of a traction sheave that is considerably smaller in diameter and lighter than those used at present. Therefore, also the moment required for moving the elevator car is low, and consequently it is possible to use a small and cheap hoisting motor. The flat band-like shape of the rope distributes the pressure imposed by the rope on the traction sheave or diverting pulley more uniformly on the surface of the traction sheave. Further, sliding of the fibers relative to each other is minimized, and so the internal shear forces in the rope are also minimized. In addition, the ratio of volume to area is low which means that frictional heat is effectively transmitted from the rope to the environment. Furthermore, the sheath of the hoisting rope can easily be coated with various materials, so the friction and abrasion characteristics can be optimized for different traction sheave materials. The small motor and small traction sheave are well applicable to an elevator without machine room because the hoisting motor with the traction sheave can be easily accommodated in the elevator shaft.

Brief Description of the Drawings

In the following, the invention will be described in detail by the aid of an example by referring to the attached drawings which are given by way of illustration only, and thus are not limitative of the present invention, and in which:

Fig. 1 presents an elevator rope arrangement according to the invention;

Fig. 2 presents another elevator rope arrangement according to the invention;

Fig. 3 presents a hoisting rope applicable to the elevator rope arrangement of the invention; and

Figs. 4-8 present different synthetic-fiber rope solutions.

Detailed Description of the Preferred Embodiments

Fig. 1 shows a traction sheave elevator according to the invention, comprising an elevator car 1 and a counterweight 2 travelling along guide rails in an elevator shaft and suspended on suspension ropes 3. The steel suspension ropes 3 are fixed to the top part of the elevator

car 1 and passed via a diverting pulley 4 in the elevator shaft to the counterweight 2. The substantially round hoisting ropes 5 used to move the elevator car and counterweight, made of synthetic material, are flexible and substantially thin as compared with the suspension ropes. The hoisting ropes are attached by their first end to the lower part of the elevator car 1, from where the ropes are passed to the lower part of the counter-weight 2 via the traction sheave 7 of a drive machine 6 placed on the bottom of the elevator shaft below the elevator car 1 and via a diverting pulley 8 placed on the bottom of the elevator shaft below the counter-weight. The drive machine is e.g. a discoid electric motor of a flat construction in relation to its diameter, with a traction sheave integrated with the rotor and having a stator and rotor whose diameter is larger than the diameter of the traction sheave. The drive machine can be mounted either on the bottom of the shaft or on the shaft wall structure in the lower part of the elevator shaft. Several hoisting ropes running side by side can be used. In the solution illustrated by Fig. 1, the friction between the hoisting ropes and the traction sheave has been increased by having the hoisting ropes pass around the traction sheave 7 so that the hoisting ropes coming down from the elevator car pass between the diverting pulley 8 and the traction sheave 7 down to the traction sheave, run around the traction sheave by its lower side and then, having passed through a partial round about the traction sheave, go further by its upper side and intersect themselves, and after the intersection they go further to the diverting pulley 8, pass the diverting pulley by its lower side and go up to the counterweight. In this embodiment, the hoisting ropes are attached to the lower part of the counterweight.

In this suspension example, several thin hoisting ropes are used, but it is also possible to use a single flat rope. In the case of a flat rope, an additional difficulty results from the rope intersecting itself because the rope has a relatively large width. However, the rope intersection can be implemented either by turning the traction sheave through an appropriate angle about its plane of rotation or by tilting the traction sheave in its plane of rotation. A further possibility is to both turn the traction sheave and tilt it as described above, in which case the angle of turn or the angle of tilt will be smaller than when the traction sheave is only turned or only tilted. When separate hoisting ropes are used, the traction sheave also has to be tilted and/or turned to allow the ropes to cross each other.

The hoisting ropes are tensioned between the elevator car and the counterweight by means of the diverting pulley 8. The tensioning is implemented using a tension spring 9, which draws the traction sheave 8 so that the hoisting ropes always remain sufficiently tight on the traction sheave to provide the required friction regardless of elongation of the hoisting ropes. The tensioning can also be implemented using an arrangement in conjunction with the hoisting machinery, in which case the diverting pulley is fixedly mounted. In this case, the mass of the hoisting machinery can be utilized for the tensioning of the hoisting rope. The hoisting machinery is supported e.g. on the vertical guide rails in the elevator shaft and so connected that its mass will assist the rope tensioning elements.

Fig. 2 presents a suspension arrangement that is better suited for a flat hoisting rope than the arrangement in Fig. 1 because the hoisting rope does not intersect itself. The hoisting ropes are suspended in the same way as in the solution presented in Fig. 1. Each hoisting rope 5 is attached by its first end to the lower part of the elevator car 1, from where the ropes are passed to the lower part of the counterweight 2 via the traction sheave 7 of a drive machine 6 placed on the bottom of the elevator shaft below the elevator car 1 and via a diverting pulley 8 placed on the bottom of the elevator shaft below the counterweight. The hoisting ropes are implemented in the same way as in Fig. 1, consisting of either a number of separate adjacent ropes or a single flat rope. The hoisting ropes descending from the elevator car go down to the traction sheave 7 by its back side as seen from the direction of the diverting pulley 8, pass around the traction sheave by its lower side and go further to the diverting pulley 8, pass around it by its lower side and go up to the counterweight. In this suspension model, however, the angle of contact between the hoisting rope and the traction sheave is substantially smaller than in the solution presented in Fig. 1, in which it may be as large as over 270°. Therefore, the friction is also smaller, so the rope must be more tightly tensioned than in the case illustrated by Fig. 1. In other respects, the tensioning is implemented in the same way as in Fig. 1.

Figures 3-6 present hoisting rope structures in which the load-bearing fibers are in strands. The strand layout is free and can be implemented either according to load capacity requirements or according to bending capacity, e.g. torsional rigidity.

Fig. 3 presents a substantially flat elevator hoisting rope 5 as used in the suspension arrangement of the invention. It comprises six bundles 12a - 12e of strands fitted in the same plane. The bundles consist of load-bearing strands 13. These longitudinal strands, which form the strength of the rope structure, are made of synthetic fibers, e.g. aramid fibers. The strands are enclosed in a sheath 14 that binds the strands together into a single structure and gives a good friction coefficient in contact with the traction sheave. The bundles 12a - 12f are fitted side by side to form a planar sheath 14, so that the width of the rope is considerably larger than its thickness. The sheath material 14 may be e.g. polyurethane, which gives a multifold friction coefficient as compared with a steel rope. If necessary, the planar surface of the sheath can be coated with various materials. The properties of the coating 15 regarding friction and wear can be optimized for different traction sheave materials. In Fig. 2, the bundles of strands are of a round shape in cross-section, but naturally, the shape can be chosen in accordance with the use.

Fig. 4 presents a flat hoisting rope solution in which the bundles 12 of strands are placed at different distances from each other. The Bundles are somewhat closer to each other near the edges than in the middle part of the hoisting rope. In the solution presented in Fig. 5, the bundles 12 of strands are placed non-symmetrically with respect to the longer midline of the hoisting rope, close to the friction surface of the rope. Fig. 6 presents a solution in which the strands and bundles 12 of strands of the hoisting rope are of different sizes in diameter. The larger bundles are placed at the edges of the rope as seen in its widthways direction, with smaller bundles placed between them. In the ways illustrated by Figures 4-6, it is possible to improve the tracking of the hoisting rope 5 as it is passing over the traction sheave or diverting pulleys.

Figures 7 and 8 present hoisting rope solutions in which the load-bearing fibers are in the form of a fabric. In the solution illustrated by Fig. 7, the fibers form in the cross-section of the hoisting rope 5 lines crossing each other in both the longitudinal and lateral directions of the hoisting rope 5. The lines may also be in a position oblique to the longitudinal direction of the hoisting rope. Thus, the fabric may resemble e.g. the clinch-built, cross-ply structure of a car's safety belt of a corresponding belt. Fig. 8 presents a hoisting rope structure in which the hoisting rope in its entire cross-sectional area consists of fabric or

fabrics bound together by a binding agent, e.g. polyurethane. By using different reinforcing fabrics, it is possible to produce a flexible hoisting rope or suspension rope in which the contacts between individual fibers can be increased or reduced as necessary.

The advantages achieved by using rope solutions as illustrated in Figures 3-8 include the following:

- When a single flat hoisting rope is used, the void space between ropes that is involved in the case of separate ropes is avoided, and thus the traction sheave can be made narrower than before.
- The cross sectional area of the load-bearing part of the rope can be optimized.
- A good degree of damping of rope vibrations is achieved because the separate ropes are now replaced with bundles of strands embedded in a mass of vibration damping material.

When a thin, band-like hoisting rope is used, it is necessary to make sure that lateral drift of the hoisting rope off the traction sheave or diverting pulley is prevented. This can be done in various ways. In one solution, the traction sheave is provided with a tilting mechanism and sensors monitoring the position of the rope edge. The traction sheave is a straight cylinder, whose axis of rotation can be tilted to bring the hoisting rope to the central part of the traction sheave. When the hoisting rope is drifted to the edge of the traction sheave, a mechanical sensor or an equivalent detector based on beam of light or the like gives a corresponding signal to the system controlling the tilting of the traction sheave, whereupon the tilt of the traction sheave is altered so that the band-like hoisting rope is brought back to the middle of the traction sheave. If necessary, it is possible to use a cambered/crowned traction sheave or diverting pulley, i.e. one with a varying diameter, in which case the circumferential surface of the sheave/pulley is either convex or concave as seen from the front of the sheave/pulley. The advantage achieved is a good retention of the hoisting rope in its proper position.

When thin separate hoisting ropes are used, the bundles 12a -12f of strands are placed apart from each other, in which case they function like independent hoisting ropes regardless of the other bundles.

As stated above, when the hoisting rope structure of the invention is used, the traction sheaves needed e.g. in the elevator suspension arrangements described above are considerably smaller in diameter and lighter than the traction sheaves currently used. The smaller traction sheave and machinery allow all elevator components to be accommodated in the elevator shaft, thus eliminating the need for a separate machine room. This brings considerable savings in the delivery price of the elevator.

It is obvious to a person skilled in the art that different embodiments of the invention are not restricted to the example described above, but that they may be varied in the scope of the claims presented below. Thus, the elevator hoisting rope need not necessarily have a round or flat cross-sectional form. Instead, it may be e.g. a triangular-belt type rope having a V-shaped cross-section, in which case it is possible to achieve a very large friction between each hoisting rope and the corresponding keyway on the traction sheave. The suspension ropes can also be made of synthetic fibers and they may include either several adjacent ropes or only one flat rope. In addition, the bundles of strands can be arranged in more than one layer, e.g. in two layers, if necessary in view of the load to be borne by the rope. The suspension ratio may also be other than the 1:1 suspension presented in the example.